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Effect of Wide Pitch at mmWave Frequencies and Design Recommendations

Daniel Bock, Ph.D.

Overview

- Introduction
- Test Objectives
- Methods
- Results
- Discussion of Recommendations of DfT at mmWave
- Summary

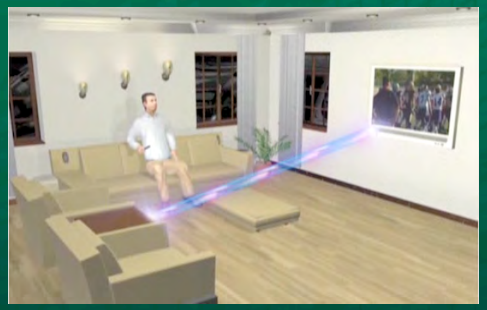
What are the Key Markets Driving mmWave Test?

- **There are four primary markets that are driving the mmWave market in test and are requiring wide pitch test:**

60 - 86 GHz
Automotive
Radar

60 GHz
Wireless Network
(802.11 ad)

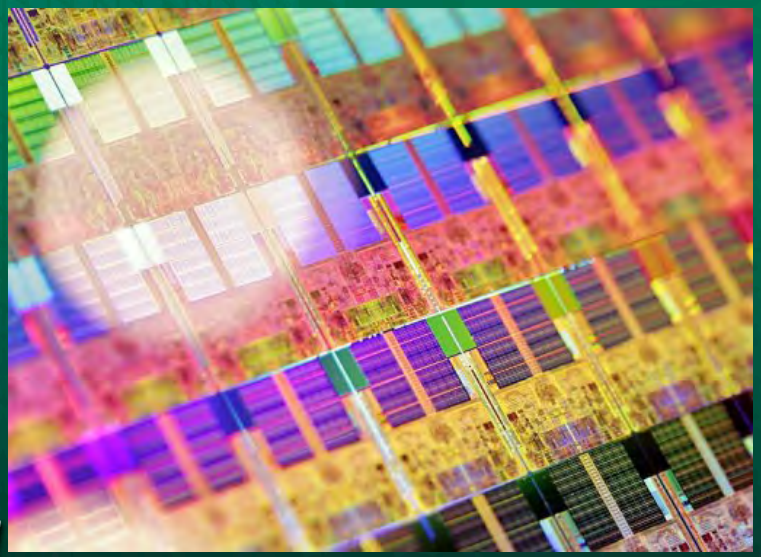
60 – 80 GHz
Wireless-HD
Multimedia

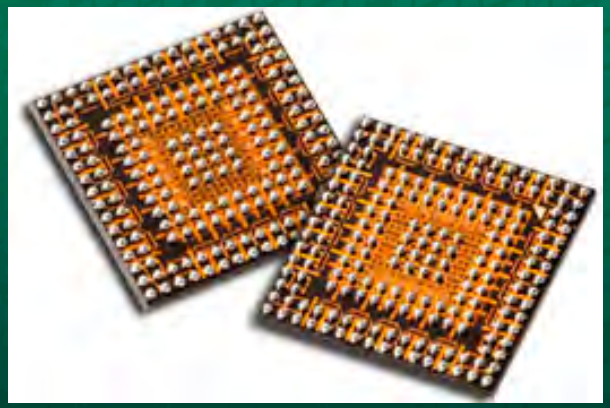


56– 86 GHz
Cell Phone
Short/Back Haul

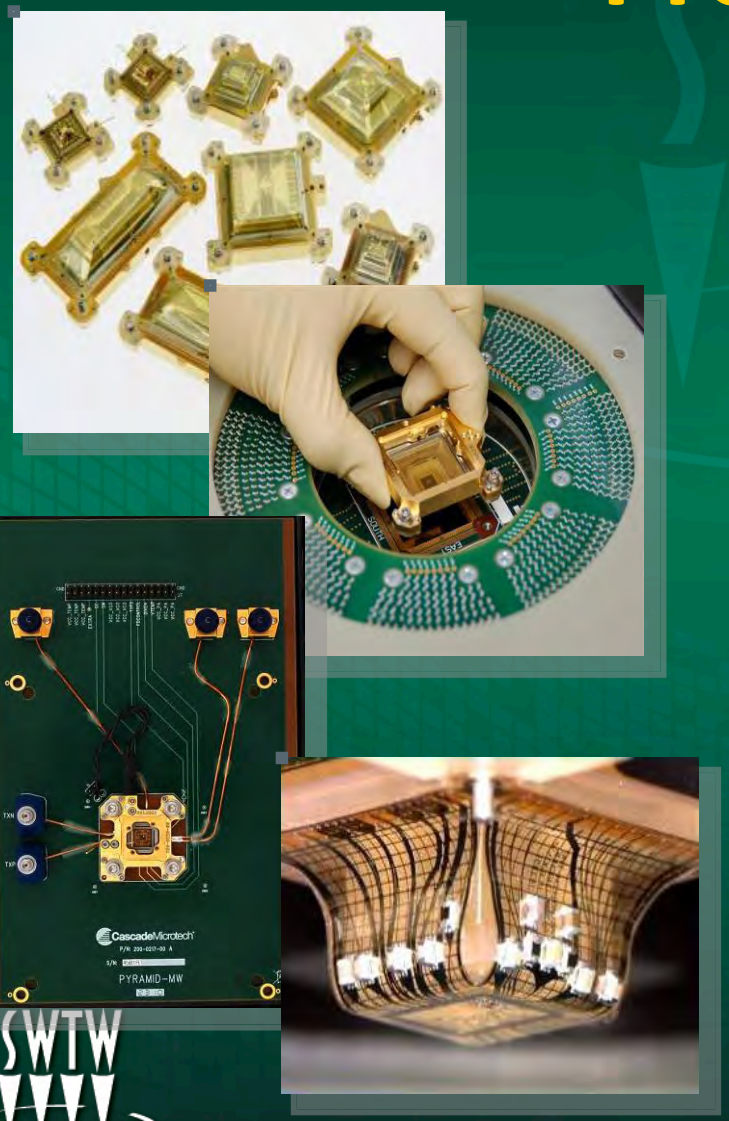
Why Wide Pitch?

- **WHY IS THE INDUSTRY GOING TO WIDE PITCH (400-500 µm)?**
  - A large number of manufacturers are moving to Wafer Level-Chip Scale Package (WL-CSP) for their devices
    - True integration of fabrication, packaging, test and burn-in test to streamline the manufacturing process
    - Reduced Package inductance for backhaul, automotive radar, and E-band RF chips
  - However, WL-CSP requires wider pitches for soldering to the PCB



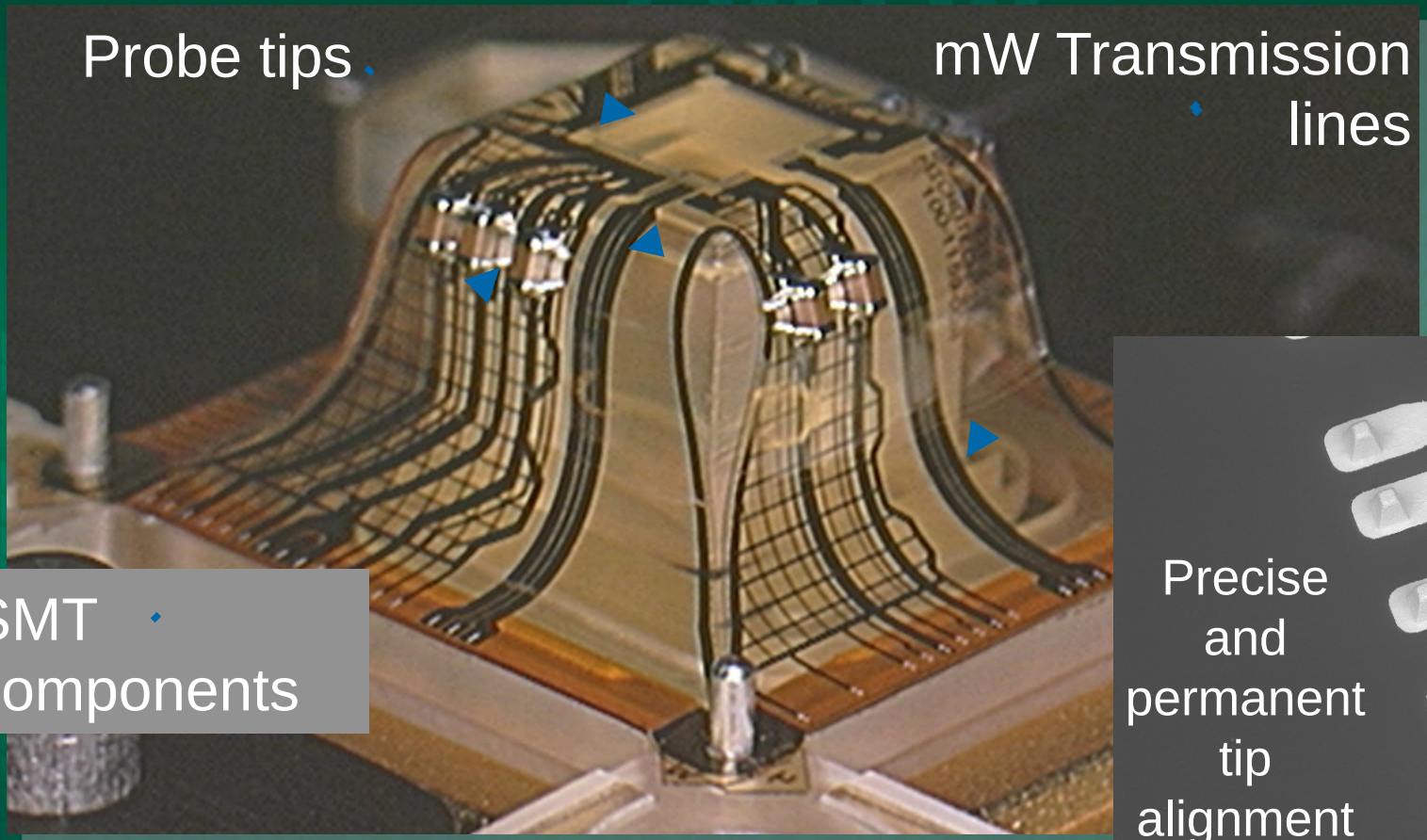


Pyramid Probe®-MW for RF KGD Production

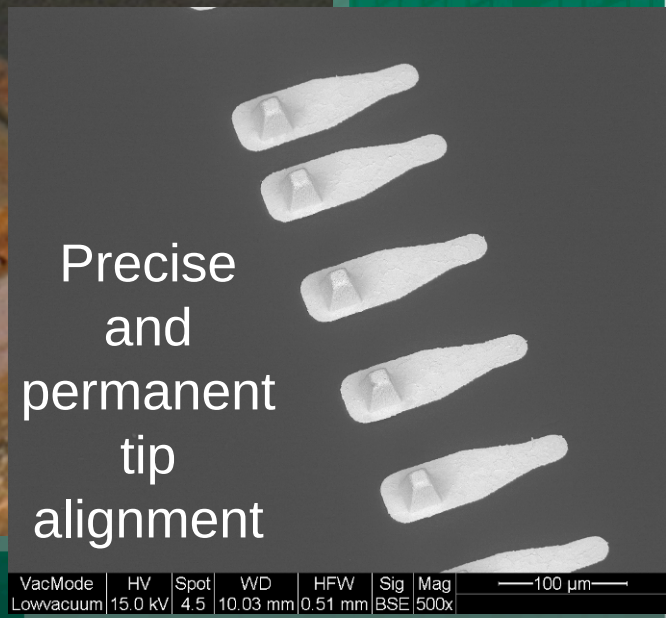


- Pyramid Probe Technology
  - Custom layout to match your die
  - Short, low-loss lines
  - Low inductance supplies with bypass capacitors close to the DUT
  - Trimmable inductors emulate package
  - Low contact resistance
  - Minimal pad damage
  - Field replaceable
  - Production, KGD test for mmWave device
- Pyramid Probe MW Advantages:
  - Frequency range to 81+ GHz on smallest frame size (RFC)
  - Wafer-level calibration for accurate measurements, repeatability

Pyramid Core for RF Testing



Wafer side view



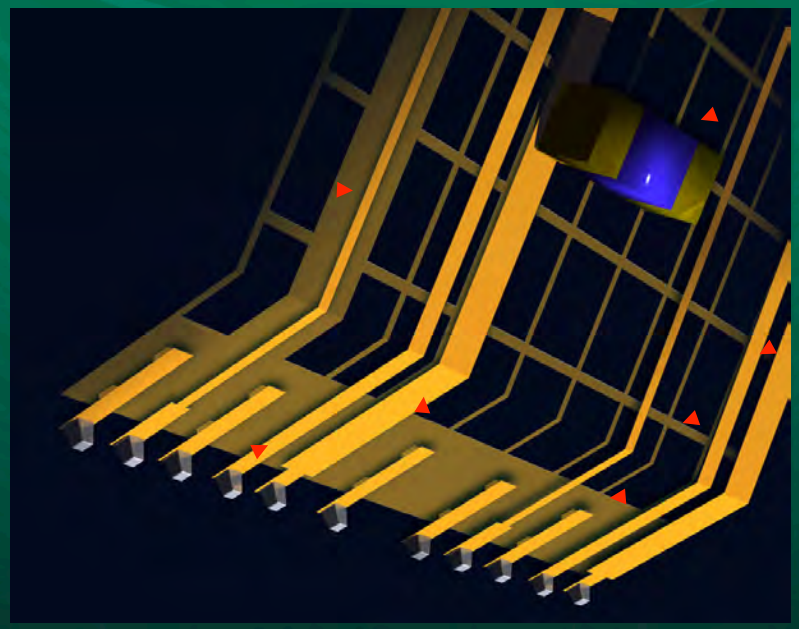
SEM photo of probe tips

Pyramid Probe Thin Film

- **The Pyramid Probe is a two-layer membrane that can handle a large variety of different signal types**
- **mmWave transmission lines use coplanar waveguide transmission lines because of their low loss**

Components within 30 ps of DUT depending on design

RF
50 Ω microstrip or coplanar waveguide



Two metal layers:
- wafer side layer is signal
- tester side layer is ground

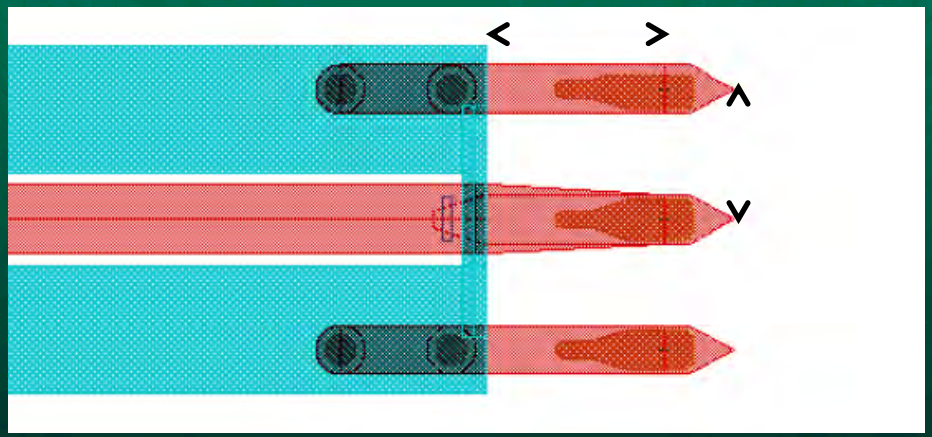
Ground inductance 0.04 nH or less to the plane

Low speed

Power supply

Why be Concerned with Wide Pitch?

- **Wide pitch is a problem primarily due to:**
  - The relatively large inductance from the separation of the RF pins and ground pins
  - Pyramid Probe cards generally have a small region (~200 µm) of uncontrolled impedance near the tips
    - Leads to more return loss due to impedance mismatch

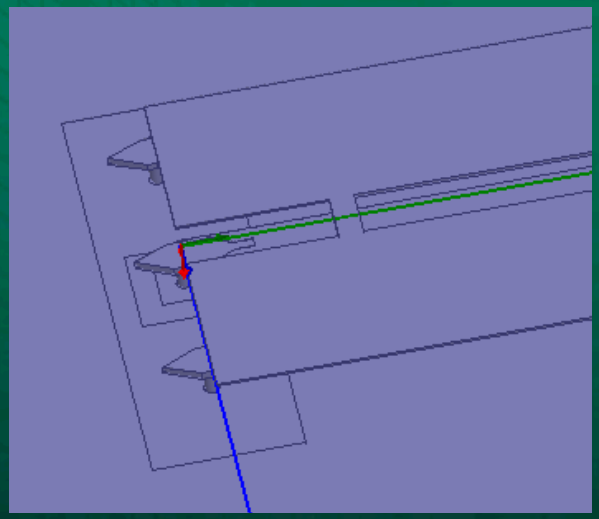


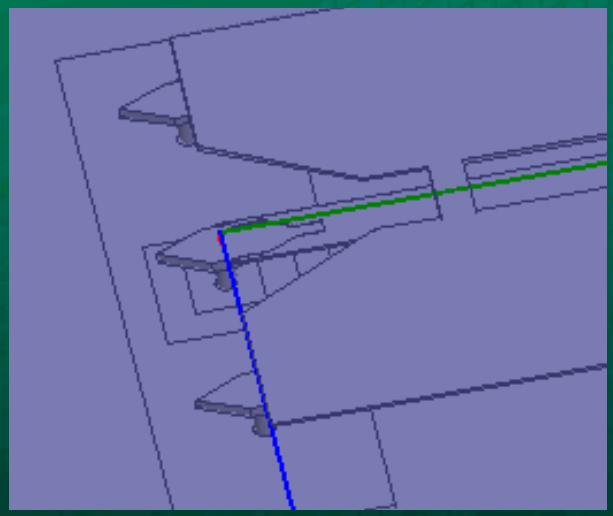
Measurement of Current mmWave Wide Pitch Production Probe

- **As the pitch increases from 100 µm pitch, the -10 dB Return Loss (RL) bandwidth is reduced**
  - Used the MSI sized membrane for tests (9.7 x 9.7 mm probing area; 408 I/O max)

How to Improve Performance at Wide Pitch?

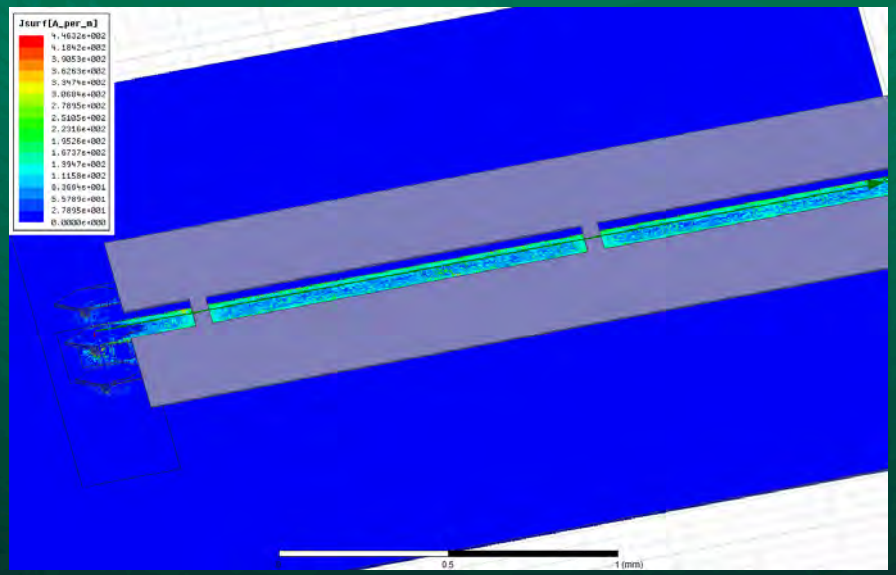
- **Add additional ground tips near the signal line for reduced return inductance**
- **Control the impedance better to the probe tips**
  - Constant gap or taper?





Wide Pitch Simulations

- **In HFSS and Microwave Office, we simulated the RF performance**
  - Optimize the return loss to better than -10 dB
  - Varied the length of taper
  - Number of probe tips tested



Simulation Recommendations

- **Simulation results indicate the following**
  - 5 GSG probe tips reduce ground return inductance

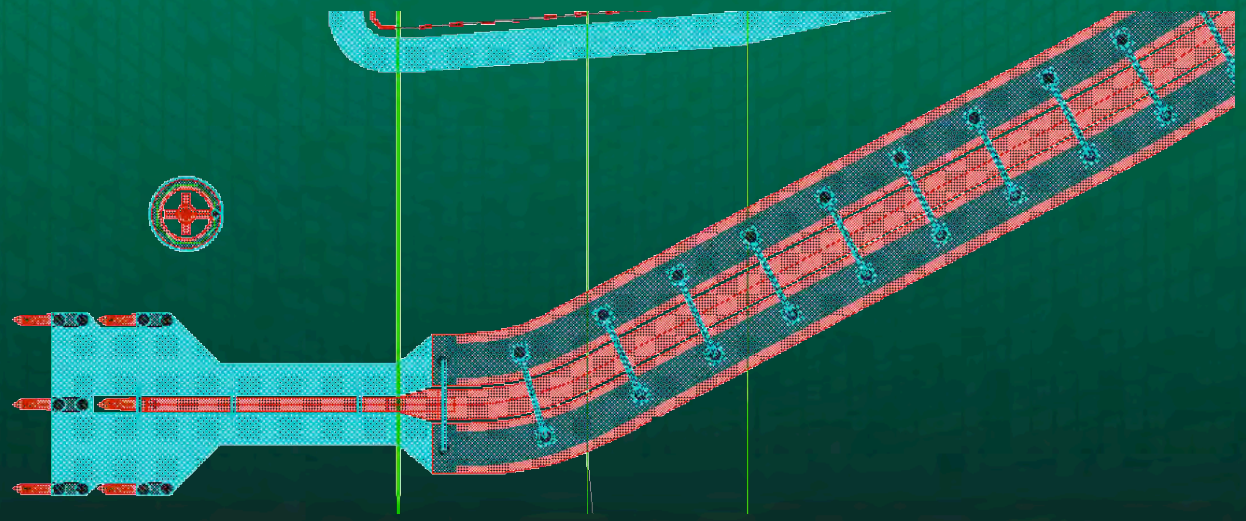
Number of Grounds (500 µm)	-10 dB RL Bandwidth
2	65 GHz
5	70 GHz

  - Keeping a constant gap around the probe tip minimizes impedance discontinuities at the probe tips

Type of Tip (500 µm)	-10 dB RL Bandwidth
Traditional	65 GHz
Long Taper	70 GHz
Short Taper	73 GHz
Constant Gap	75 GHz

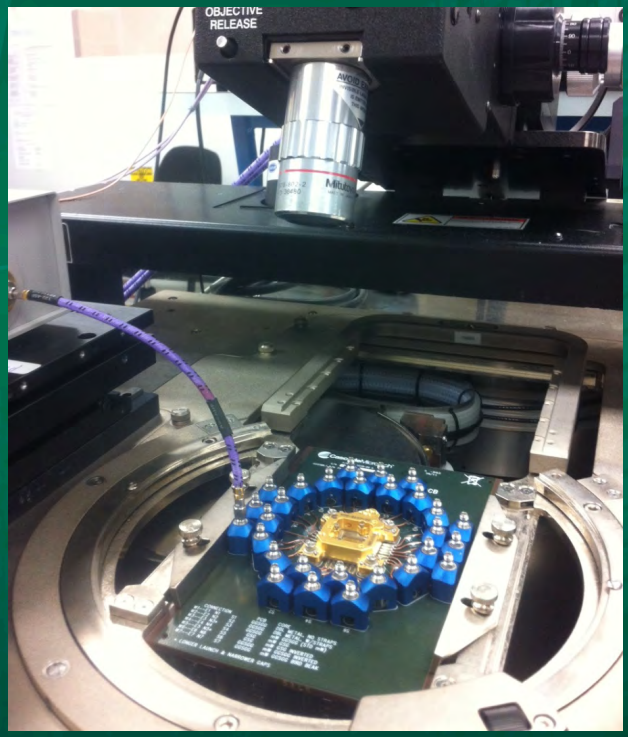
Pitch vs. Return Loss Experiment

- **Based on the simulations, we manufactured a series of probe cards to test the performance**
- **The experiments included:**
  - The standard probe tip area design
  - 2 different tapers
  - Constant gap around the probe tip
  - Tested 2 grounds versus 5 grounds at wide pitch (300 µm to 500 µm)



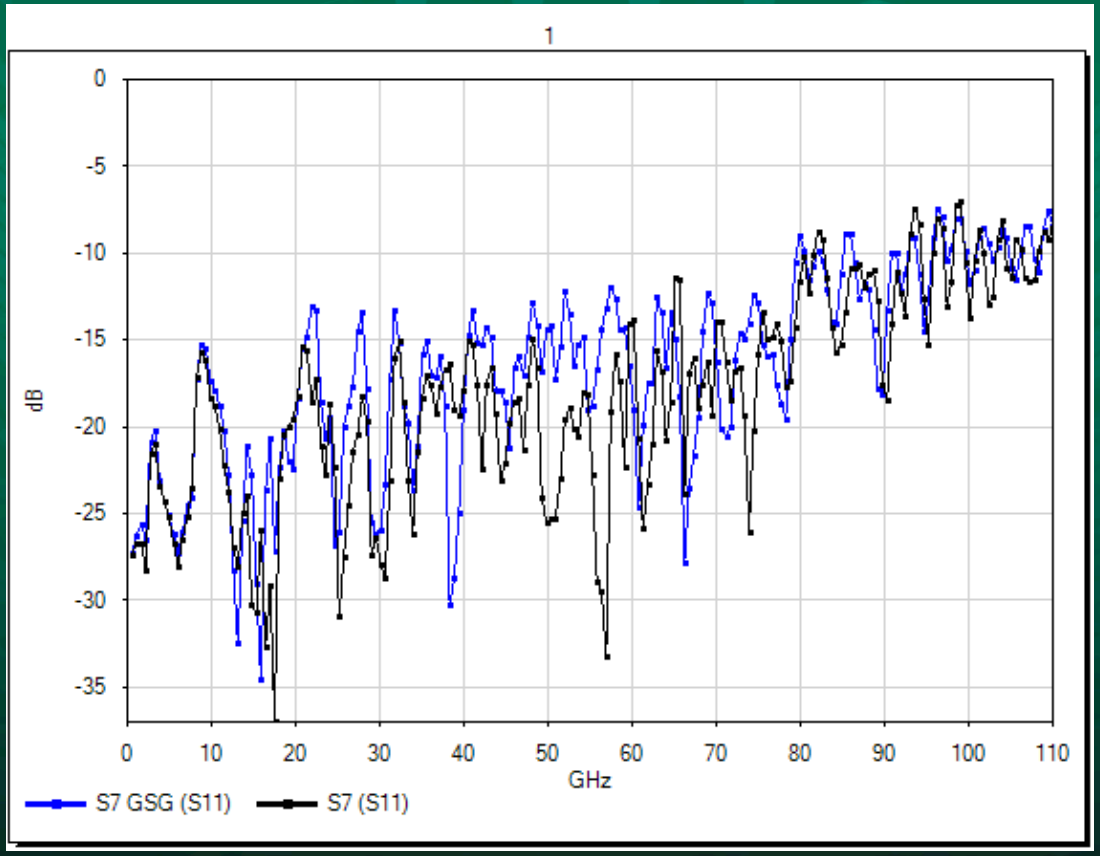
Test Setup

- **Tests were conducted in our facility in Beaverton, Oregon**
- **Equipment included:**
  - Agilent 67 GHz PNA which included extenders to 110 GHz
  - 1 mm coaxial cable
  - Cascade Microtech Summit 12000 Station
  - PC running WinCal™
  - All 2-port parameters were collecting using SOL measurements of the Pyramid Probe
  - 106-686 calibration substrate made by Cascade Microtech



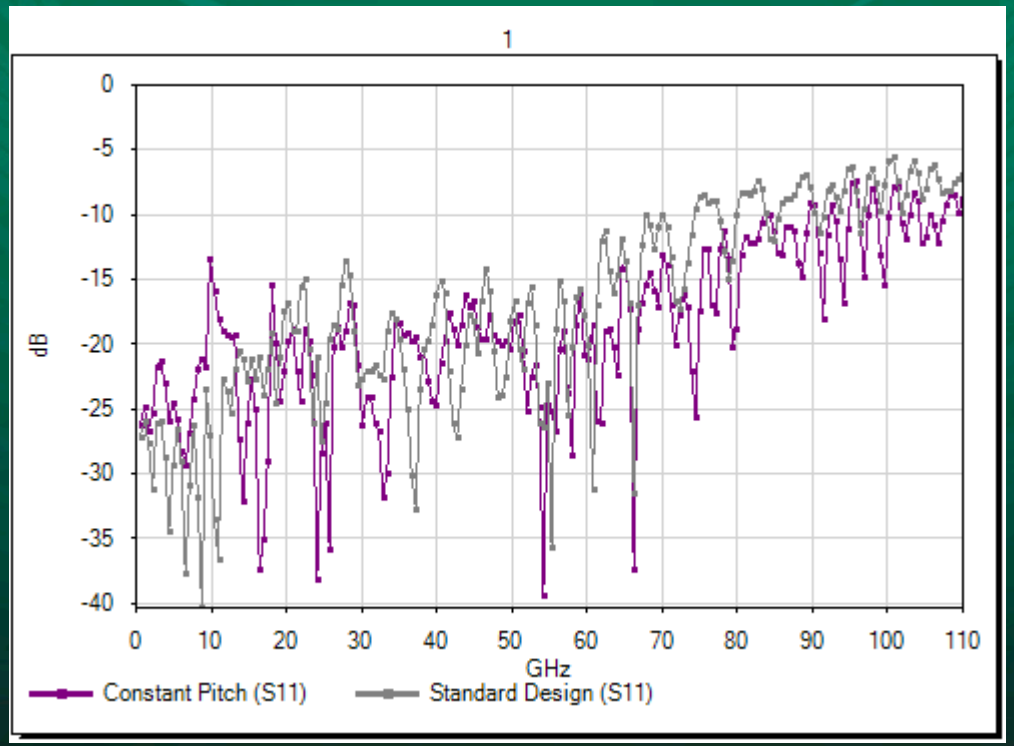
500 µm GSG Return Loss

- **This shows a comparison of two lines**
  - One has GSG – 80 GHz
  - One has S with 5 G's nearby – 82 GHz



Data Results: Ground Gap

- **The results of the gap around the probe tips indicate that the best design is for constant gap around the probe tips**
  - 67 GHz versus 82 GHz (500 µm)



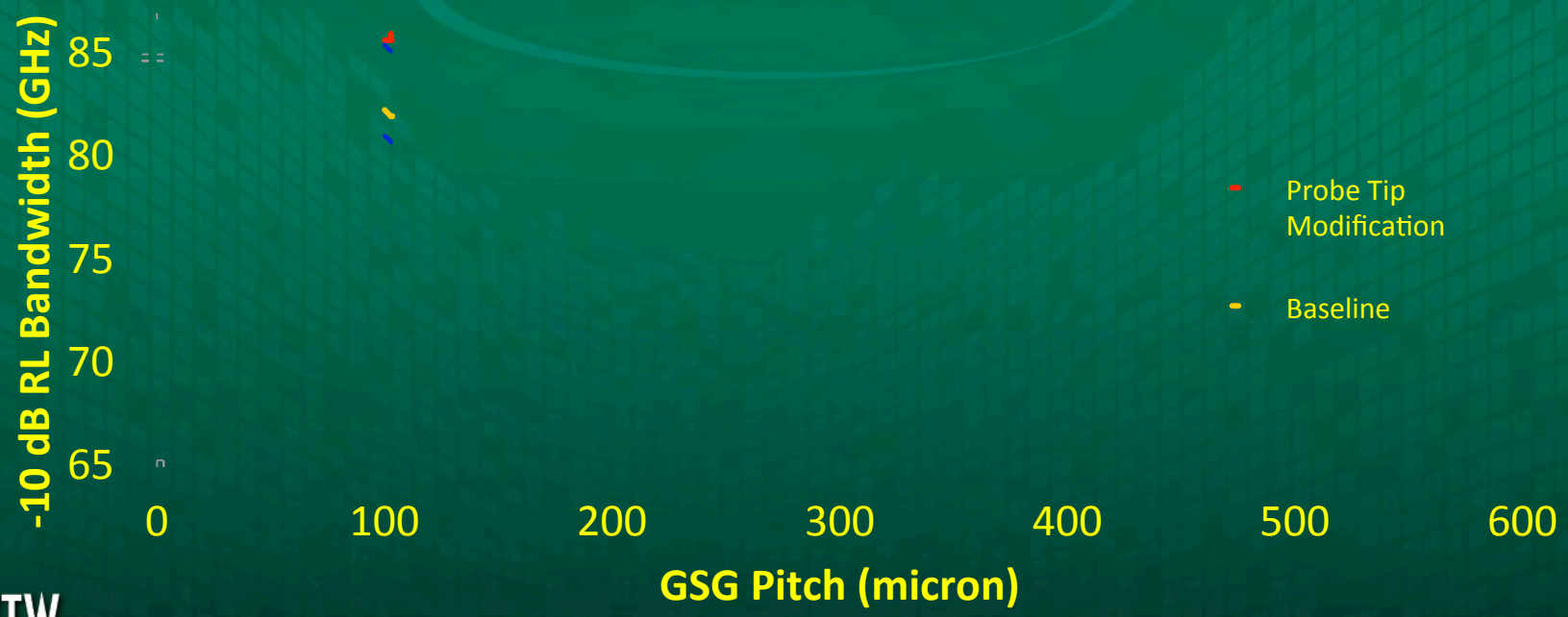
Data Table of Results

- **Data was then compiled and put into a table for comparison**
  - For 300 micron and above, the 'Tight Ground Bandwidth' column includes 5 ground tips

Pitch (µm)	Standard Probe Tip Bandwidth (GHz)	Tight Ground Bandwidth (GHz)
100	82	82
150	75	85
200	75.4	78.4
250	73.4	80.4
300	70	84
350	71	81
500	67	82

Cascade Microtech Summary of Wide Pitch Experiments

- Results show that with the Pyramid Probe, it is possible to have nearly a flat -10 dB bandwidth versus pitch on our product to support automotive radar and backhaul



Summary

- **Cascade Microtech has recommendations on DUT design in order to maximize RF performance on test**
  - Ideal layout
    - Probe - Constant gap around probe tips
    - Device - 5 ground tips for 300 um and above pitch
  - Non-ideal layout
    - 2 ground tips per signal is possible but with a few GHz reduction in performance
- **Cascade Microtech has researched improved design to increase the -10 dB Return Loss bandwidth to beyond 80 GHz to meet market requirements**

Questions?